

Geolocation validation of CERES instruments using radiance measurements

Peter Spence^a, Phillip Hess^a, Kory Priestley^b

^aScience Applications International Corporation (SAIC)

^bAtmospheric Sciences, NASA Langley Research Center

**SPIE International Symposium on Optical Science and
Technology, 03-08 August 2003, San Diego, California**



NASA Langley Research Center

Atm**spheric**
SCIENCES

Outline of Talk

- **Coastline Detection Concept**
- **Error Analysis**
- **Results**
- **Conclusions**



NASA Langley Research Center

Atm**spheric**
SCIENCES

CERES Instruments

- **5 Instruments on 3 Satellite Platforms**
 - TRMM (PFM) (no longer operational)
 - Terra (FM1, FM2)
 - Aqua (FM3, FM4)
- **3 Sensors per instrument**
 - Shortwave (0.3 μm – 5.0 μm)
 - Window (8.0 μm – 12.0 μm)
 - Total (0.3 μm – >100 μm)



NASA Langley Research Center

Atm**spheric**
SCIENCES

Coastline Detection Concept

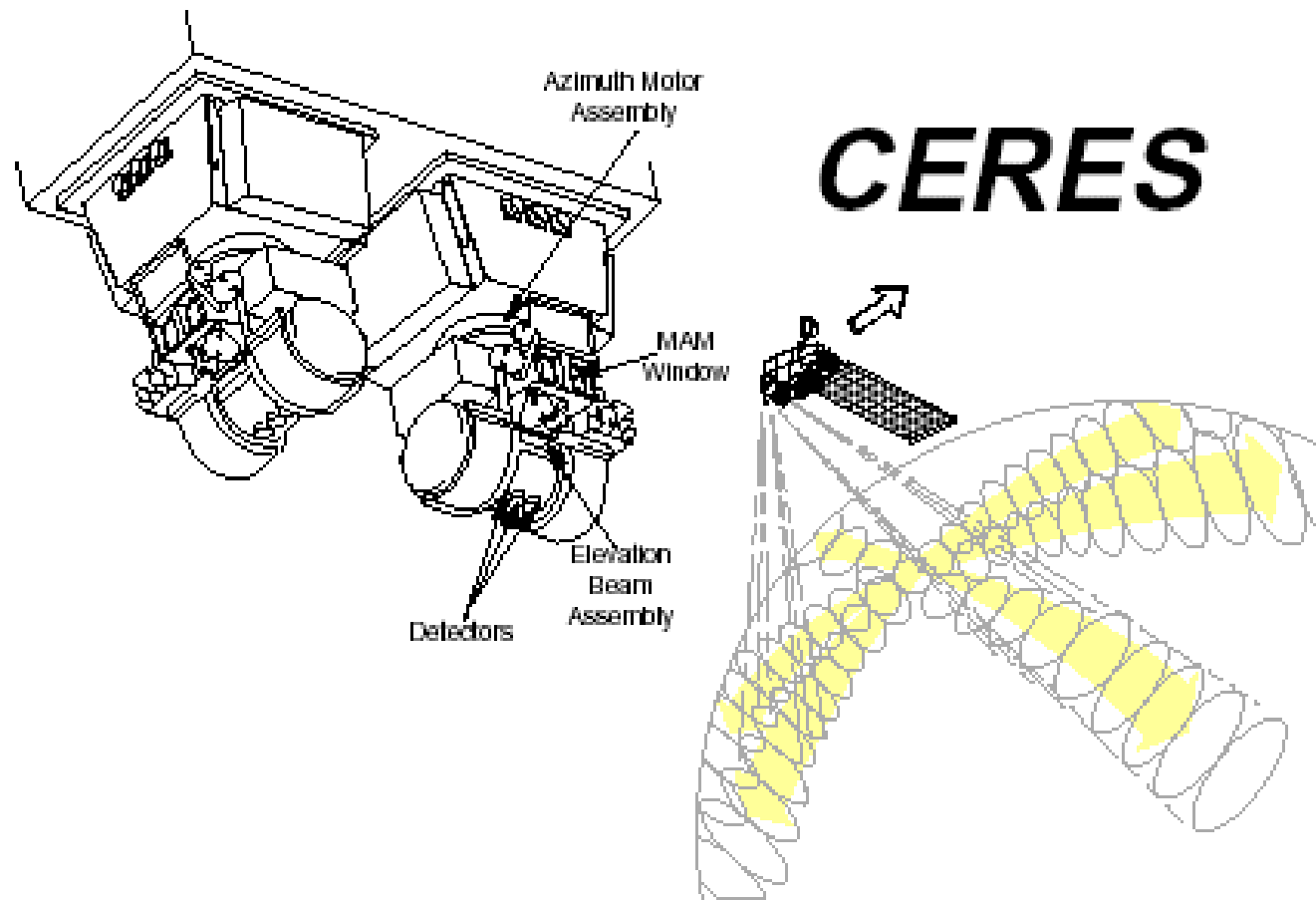
- **During limb-to-limb scans:**
 - Detect clear sky hot/cold radiance gradients provided by land-water boundaries (coastlines)
 - Determine corresponding geodetic coordinates
- **Compare with digital coastline map**
- **Calculate along-track and cross-track distance errors.**



NASA Langley Research Center

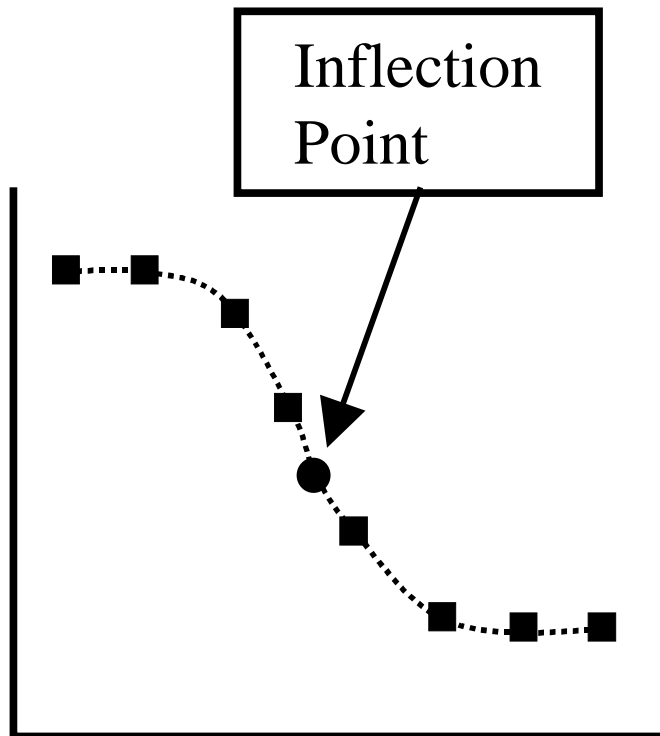
Atm**spheric**
SCIENCES

Scanning Operations



NASA Langley Research Center

Atmospheric
SCIENCES

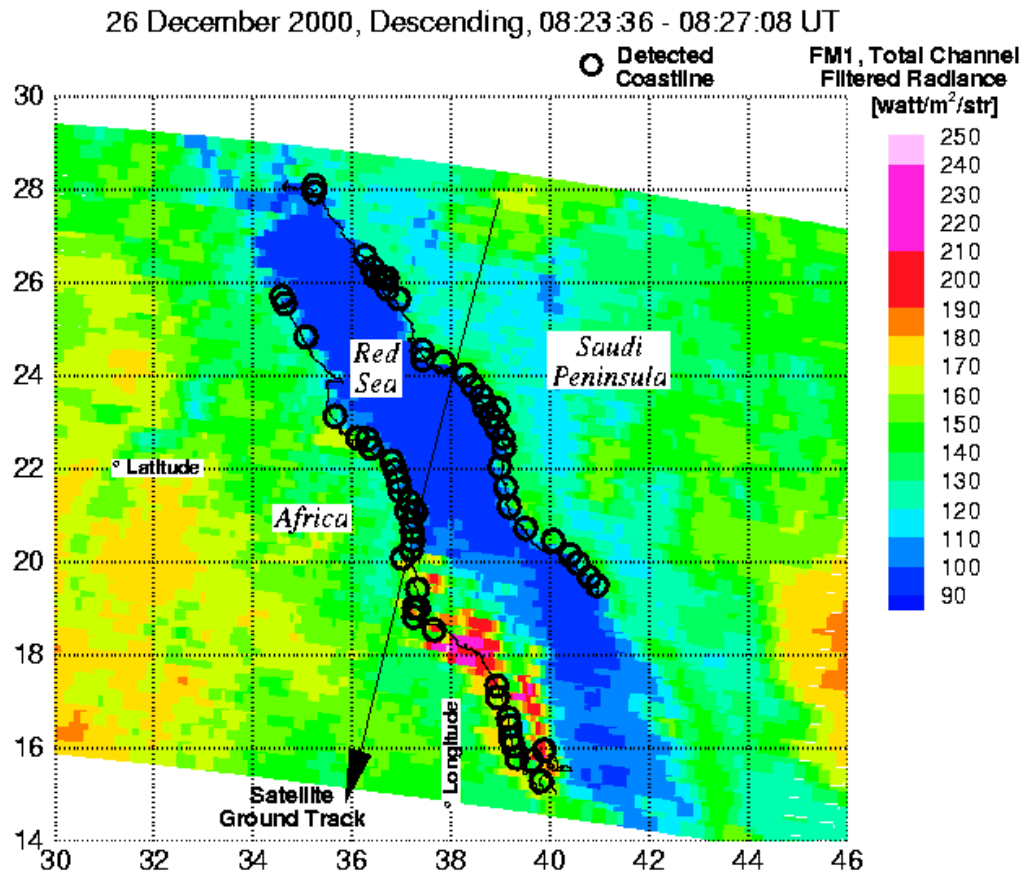


- **Fit a cubic to a contiguous set of 4 points.**
- **Find inflection point (e.g. 2nd derivative = 0).**
- **Inflection points between point 2 and 3 to represent sharp transitions or coastlines.**



NASA Langley Research Center

Atm**spheric**
SCIENCES



- Groups of N nearly contiguous points represent a coastline segment.
- Each coastline segment represents one sample in the analysis.

NASA Langley Research Center

Atmospheric
SCIENCES

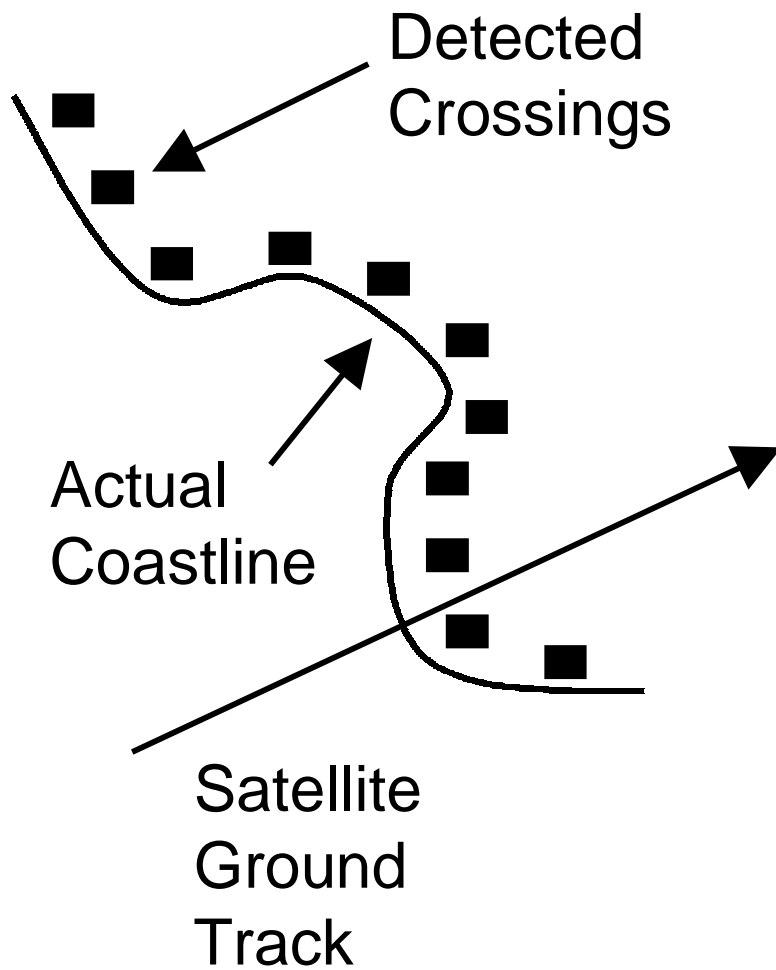
Error Analyses

- Compares computed coordinates with digital coastline map coordinates using Amoeba Error Analysis.
- Adjusts using downhill simplex minimization algorithm to minimize rms angular map crossing distances.
- Derives along-track and cross-track distances.
- Classify detected scenes:
 - Inflection points within 20km of digital map.
 - Inflection thresholds [$>10 \text{ w-m}^{-2} \text{ sr}^{-1} \text{ day}$, $>2 \text{ w-m}^{-2} \text{ sr}^{-1} \text{ night}$]
 - $\pm 70^\circ$ latitude.



NASA Langley Research Center

Atmospheric
SCIENCES



- Calculate distances to nearest map points (error).
- Shift data points up/down and left/right, calculate error. Iterate until error is minimized.
- Translate latitude and longitude errors to along-track and cross-track errors.
- Plot along-track and cross-track errors on a scatter diagram.

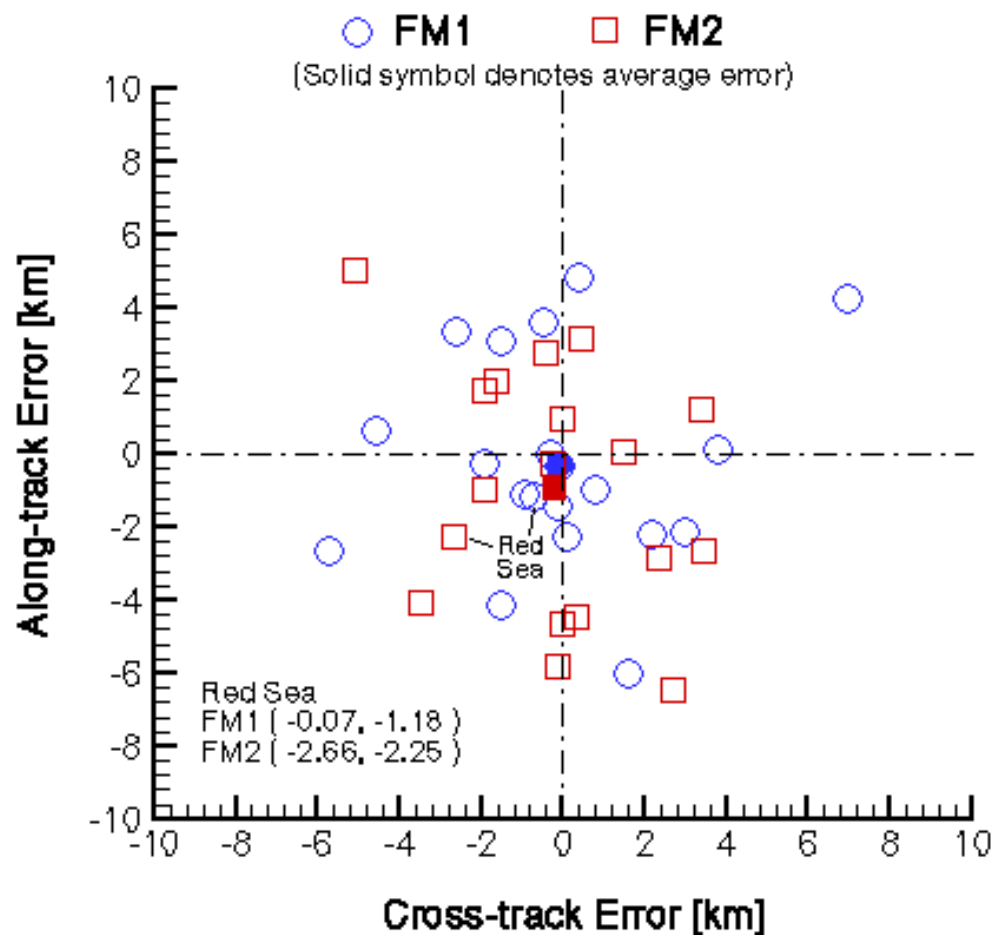


NASA Langley Research Center

Atm**spheric**
SCIENCES

Terra/CERES Coastline Detection

28 February 2000, Error Analysis



NASA Langley Research Center

Atmospheric
SCIENCES

Results (Scatter Diagram)

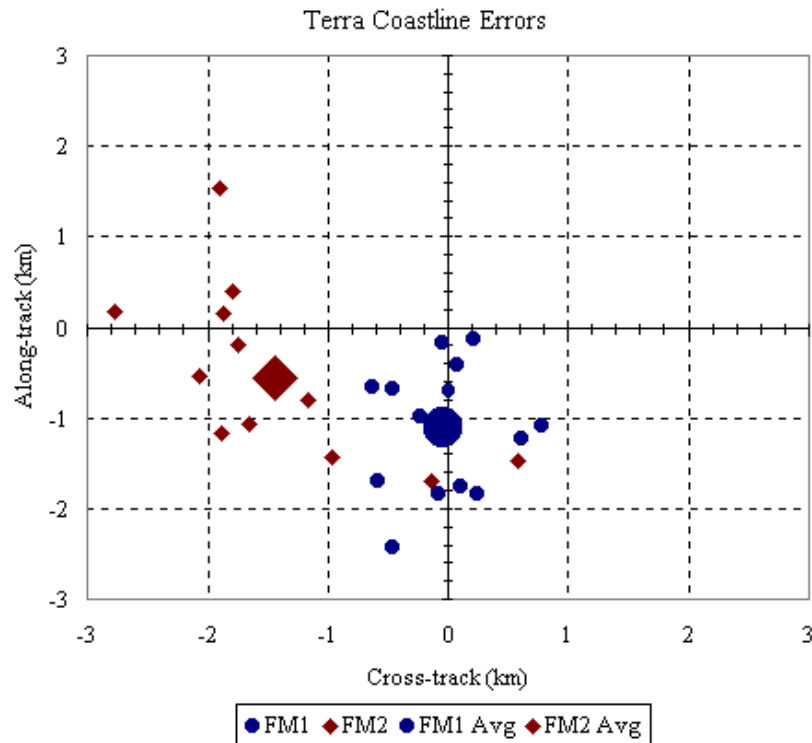
- **Terra (3 year period):**
 - **FM1** **Along-track :** ~1.1 km Aft
 Cross-track: ~0 km
 - **FM2** **Along-track :** ~0.5 km Aft
 Cross-track: ~1.5 km Lag
- **Aqua (1 year period):**
 - **FM3** **Along-track :** ~0.8 km Aft
 Cross-track: ~1.4 km Lead
 - **FM4** **Along-track :** ~0.1 km Lead
 Cross-track: ~0.5 km Lag



NASA Langley Research Center

Atm**spheric**
SCIENCES

Results (Scatter Diagram)

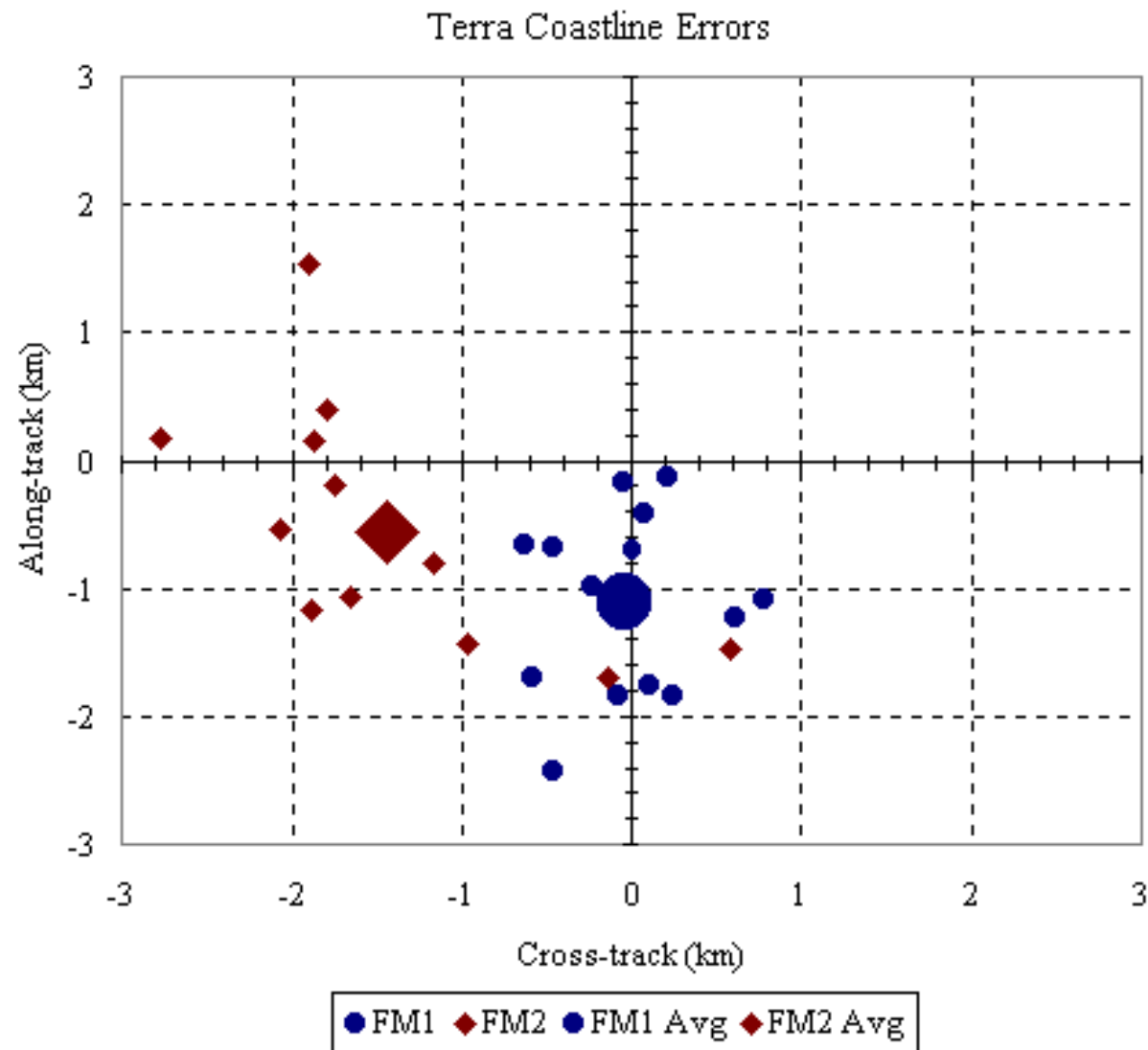


- **Terra (3 year period):**
 - **FM1 Along-track : ~1.1 km Aft**
Cross-track: ~0 km
 - **FM2 Along-track : ~0.5 km Aft**
Cross-track: ~1.5 km Lag

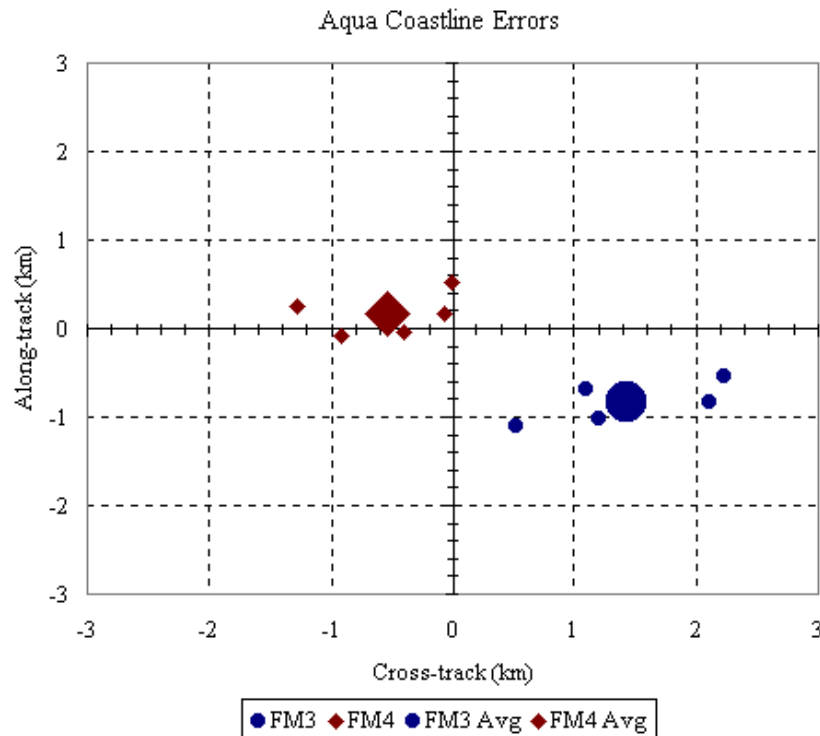


NASA Langley Research Center

Atmospheric
SCIENCES

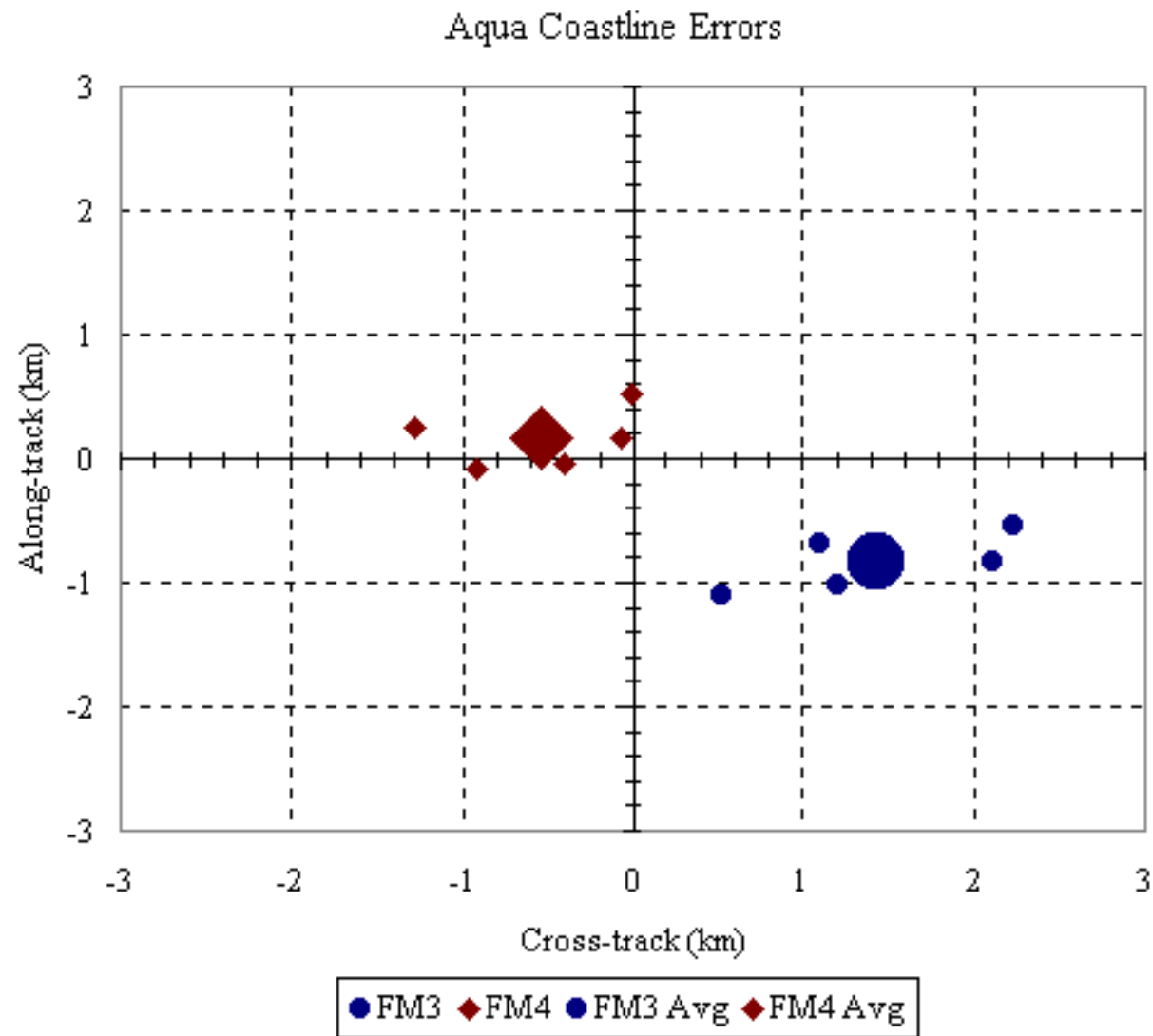


Results (Scatter Diagram)



- **Aqua (1 year period):**
 - **FM3 Along-track : ~0.8 km Aft**
Cross-track: ~1.4 km Lead
 - **FM4 Along-track : ~0.1 km Lead**
Cross-track: ~0.5 km Lag





NASA Langley Research Center

Atmospheric
SCIENCES

Results (Trending)

- **Terra (3 year period):**
 - **FM1** **Along-track :** $\sim 1.1 \pm 0.7$ km Aft
 Cross-track: $\sim 0 \pm 0.4$ km
 Radius: $\sim 1.2 \pm 0.7$ km
 - **FM2** **Along-track :** $\sim 0.5 \pm 0.9$ km Aft
 Cross-track: $\sim 1.5 \pm 0.8$ km Lag
 Radius: $\sim 1.9 \pm 0.4$ km



NASA Langley Research Center

Atmospheric
SCIENCES

Results (Trending)

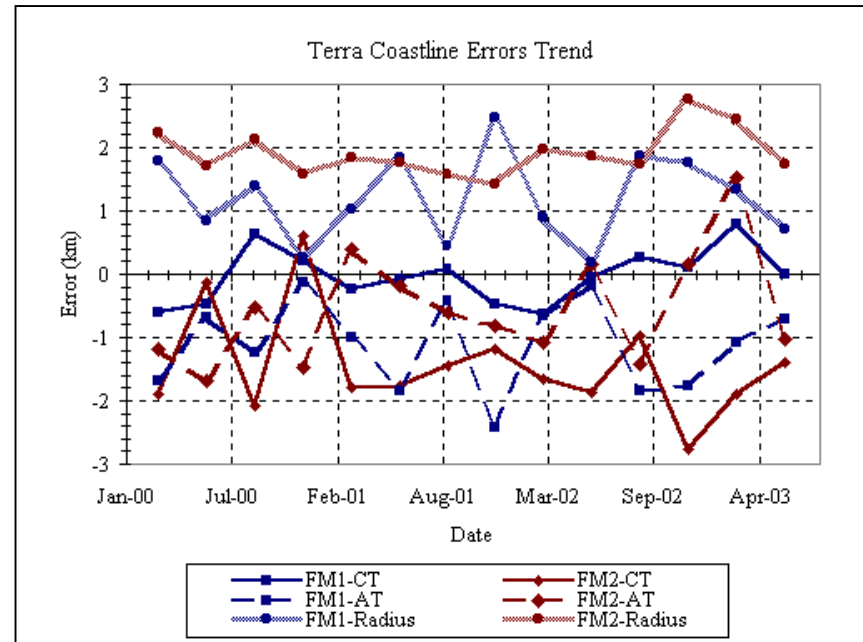
- **Aqua (1 year period):**
 - **FM3** **Along-track :** $\sim 0.8 \pm 0.2$ km Aft
 Cross-track: $\sim 1.4 \pm 0.7$ km Lead
 Radius: $\sim 1.7 \pm 0.5$ km
 - **FM4** **Along-track :** $\sim 0.1 \pm 0.2$ km Lead
 Cross-track: $\sim 0.5 \pm 0.5$ km Lag
 Radius: $\sim 0.7 \pm 0.4$ km



NASA Langley Research Center

Atmospheric
SCIENCES

Terra Results (3 Year Trending)



FM1:

- Along-track : $\sim 1.1 \pm 0.7$ km Aft
- Cross-track: $\sim 0 \pm 0.4$ km
- Radius: $\sim 1.2 \pm 0.7$ km

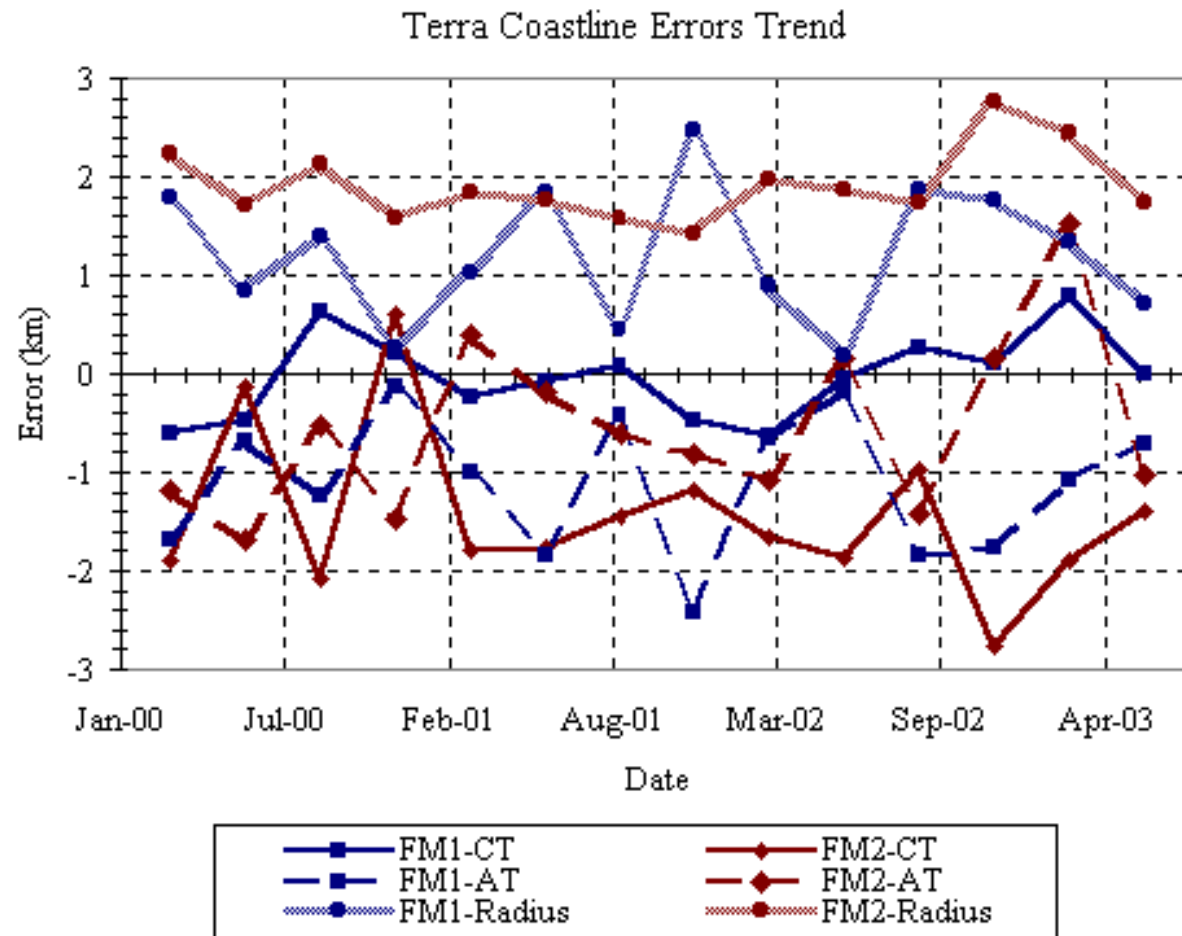
FM2:

- Along-track : $\sim 0.5 \pm 0.9$ km Aft
- Cross-track: $\sim 1.5 \pm 0.8$ km Lag
- Radius: $\sim 1.9 \pm 0.4$ km



NASA Langley Research Center

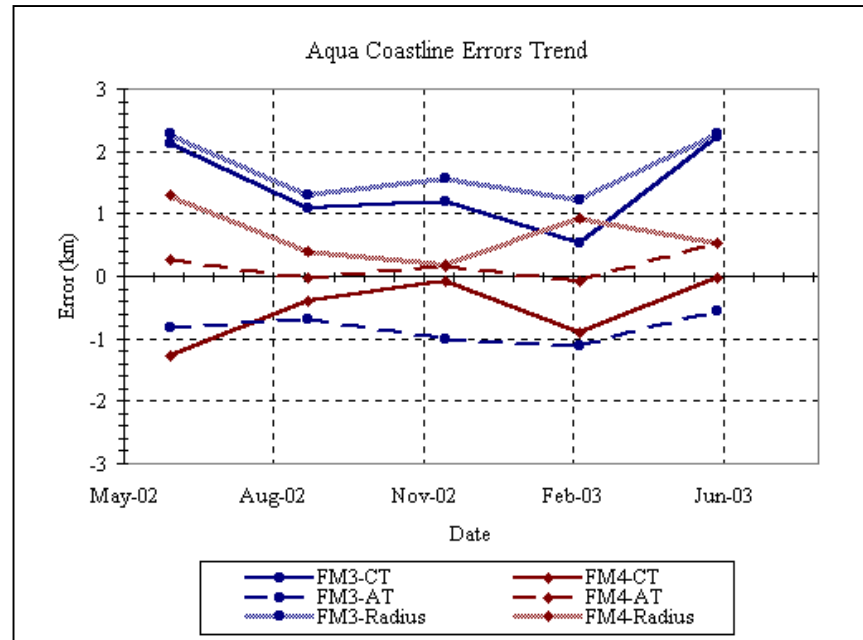
Atmospheric
SCIENCES



NASA Langley Research Center

Atmospheric
SCIENCES

Aqua Results (1 Year Trending)



FM3:

- Along-track : $\sim 0.8 \pm 0.2$ km Aft
- Cross-track: $\sim 1.4 \pm 0.7$ km Lead
- Radius: $\sim 1.7 \pm 0.5$ km

FM4:

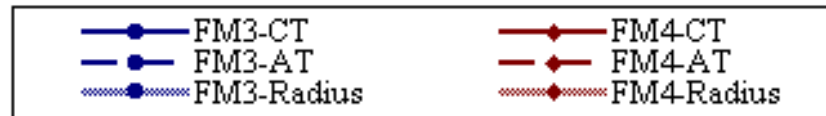
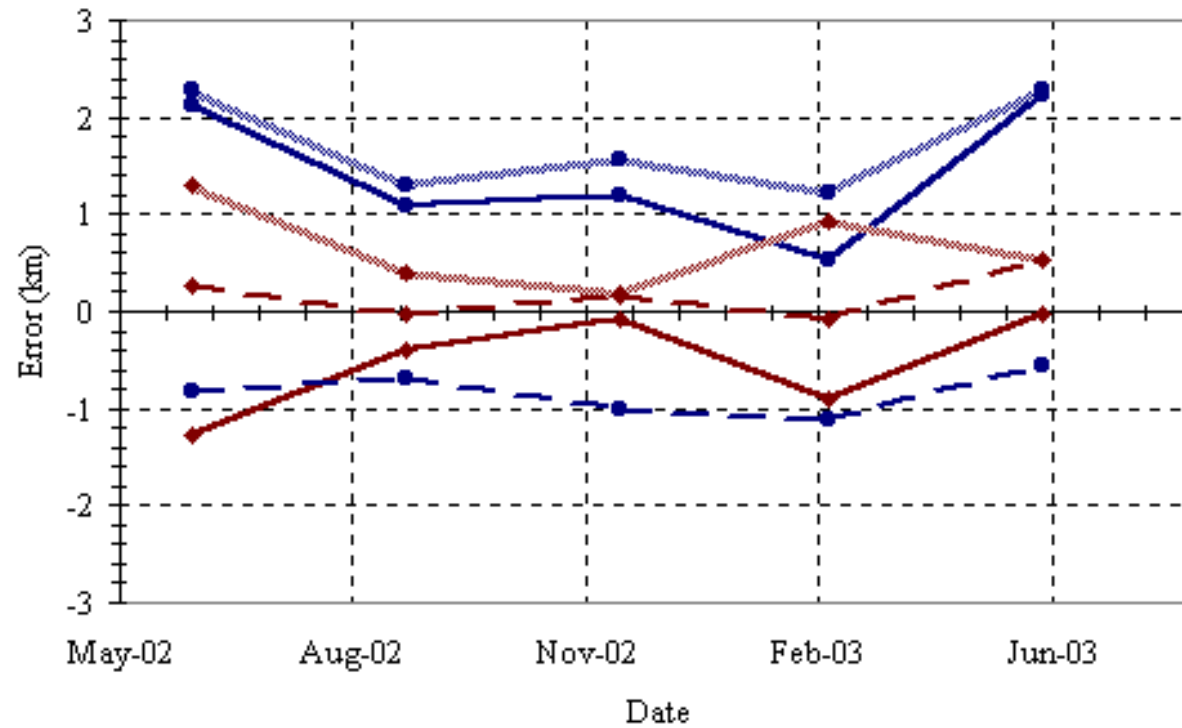
- Along-track : $\sim 0.1 \pm 0.2$ km Lead
- Cross-track: $\sim 0.5 \pm 0.5$ km Lag
- Radius: $\sim 0.7 \pm 0.4$ km



NASA Langley Research Center

Atmospheric
SCIENCES

Aqua Coastline Errors Trend



NASA Langley Research Center

Atmospheric
SCIENCES

Conclusions

- **Automated coastline detection a valuable tool to validate pointing accuracy and knowledge.**
- **Pointing errors shown to be $<10\%$ of CERES 20 km footprint on both the Terra and Aqua spacecrafts.**
- **Trends continue to indicate nominal pointing stability over time.**



NASA Langley Research Center

Atm**spheric**
SCIENCES

Backup Slides



NASA Langley Research Center

Atm**spheric**
SCIENCES

Coastline Detection

- Automated coastline detection
- Analyzed 20 FM1 scenes, 18 FM2 scenes occurring on 28 February 2000
- Initial results indicate low navigational errors for both instruments



NASA Langley Research Center

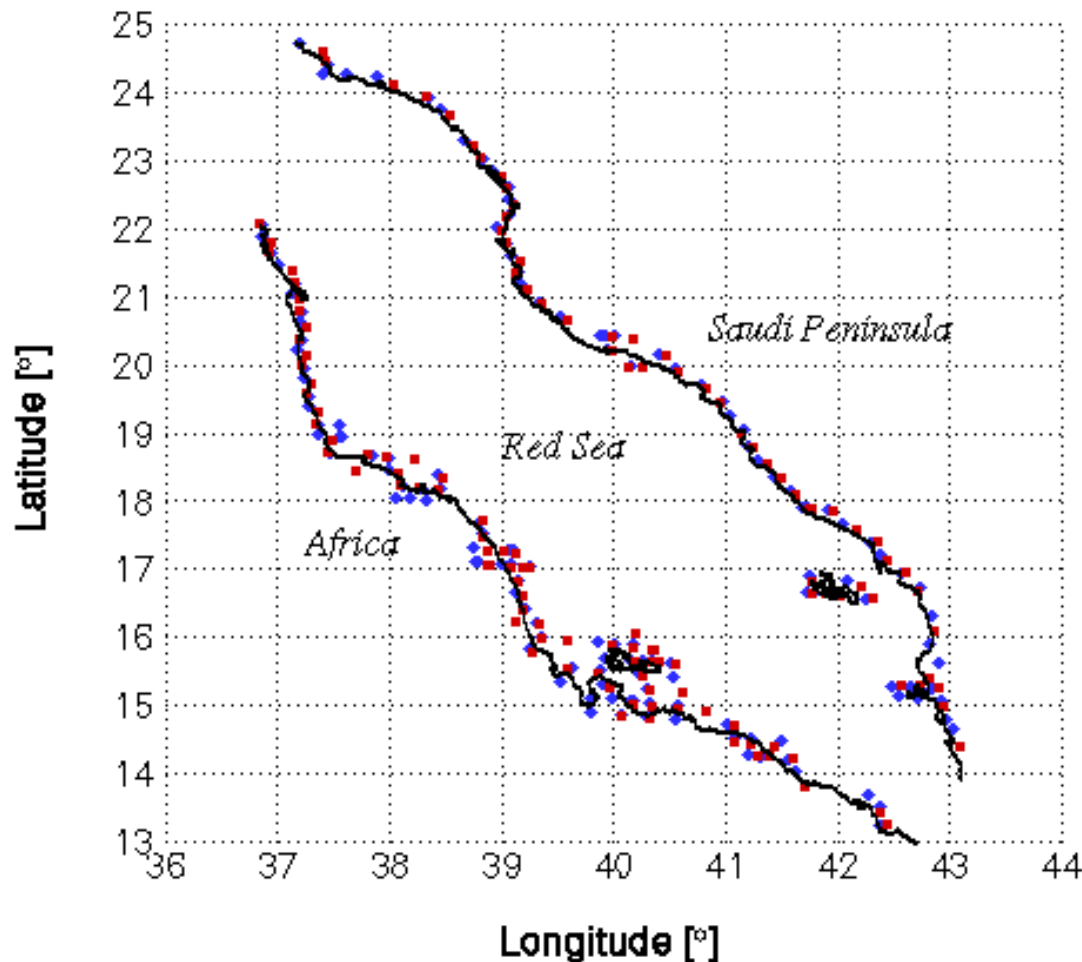
Atm**spheric**
SCIENCES

Terra/CERES Coastline Detection

28 February 2000, 20 km Square Search

● FM1

■ FM2



- Groups of N nearly contiguous points represent a coastline segment.
- Each coastline segment represents one sample in the analysis.

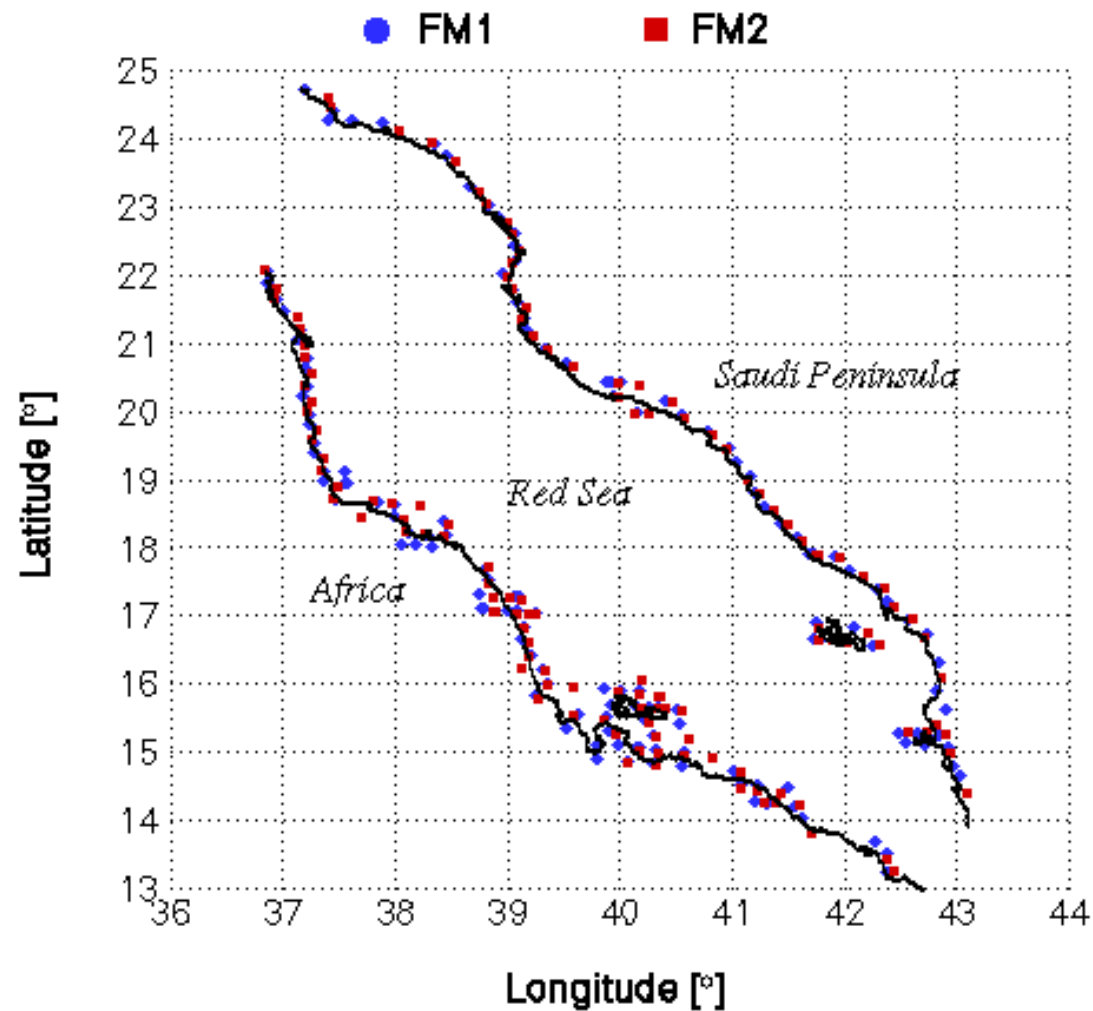


NASA Langley Research Center

Atmospheric
SCIENCES

Terra/CERES Coastline Detection

28 February 2000, 20 km Square Search

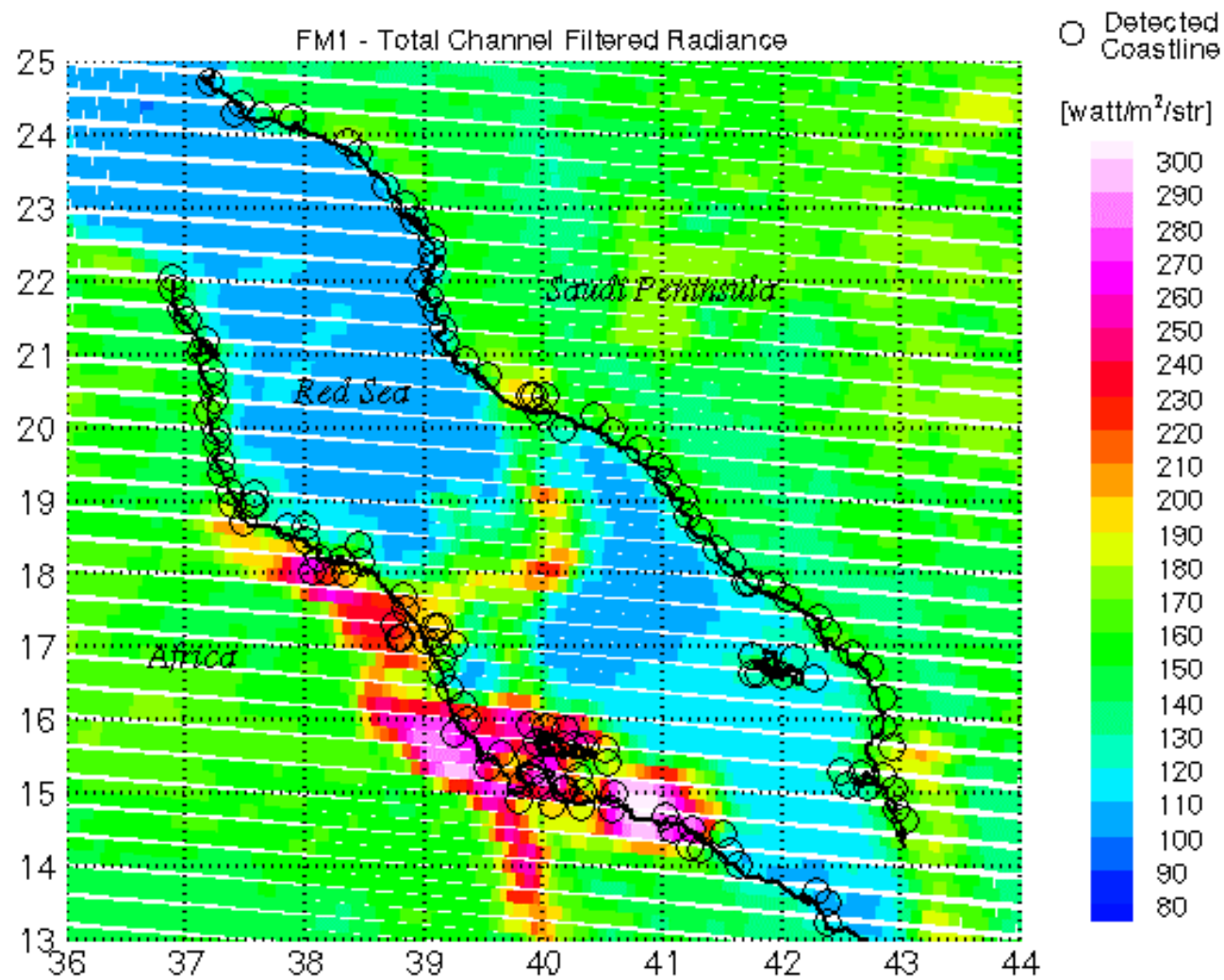


NASA Langley Research Center

Atmospheric
SCIENCES

Terra/CERES Coastline Detection

28 February 2000, Descending, 08:10:00 - 08:20:00 UT

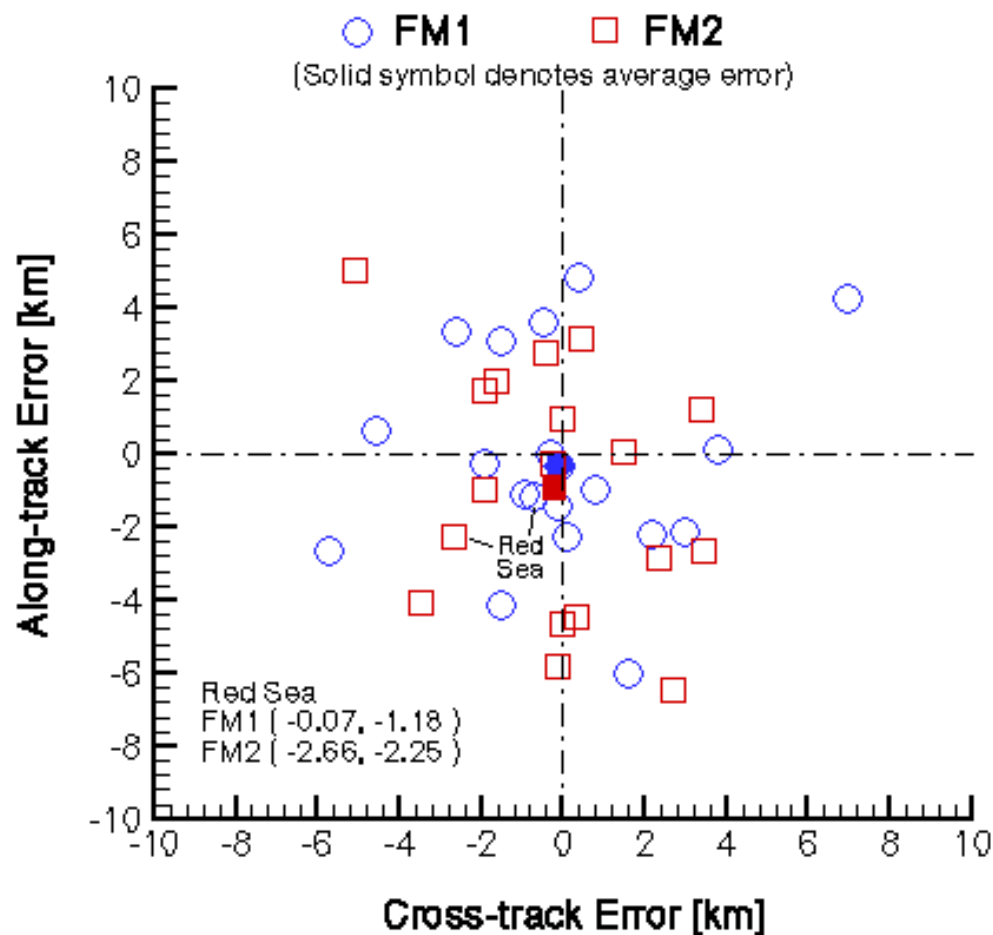


NASA Langley Research Center

Atmospheric
SCIENCES

Terra/CERES Coastline Detection

28 February 2000, Error Analysis



NASA Langley Research Center

Atmospheric
SCIENCES